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Why Are There So Many Species of Weevils?

Winfield Sterling

Female Anthonomus grandis *(the cotton boll weevil) digging oviposition hole.*

With more than three-quarters of a million different named kinds, insects are the most diverse and probably most numerous living things on Earth. There are 29 major groupings of insects, but most can be placed into any one of four different groups: Hymenoptera (wasps, bees and ants); Diptera (flies); Lepidoptera (butterflies and moths); and Coleoptera (beetles). One particularly diverse group of beetles, the weevils, is the focus of my research.

Almost 50,000 species of Curculionidae, or weevils, have been recognized and formally named by scientists. Consider that there are only about 42,000 species of vertebrates and you realize that 50,000 weevil species is an astounding number. In fact, one in every twenty species of living organisms known on Earth is a weevil. Let me try to explain why I think this diversity has evolved.

Virtually all weevils eat living plants, or are associated in various other ways with plants or plant products. Almost all plant taxa in both terrestrial and freshwater habitats, and all plant parts, are eaten by weevils. Most species of weevils are associated with flowering plants (angiosperms), although members of a few closely related groups tend to be associated with more primitive plants, such as conifers and cycads. Such apparently restricted food habits in such a diverse group may appear paradoxical. However, the nature and history of the association with plants and a single "key adaptation," are probably responsible for the proliferation of species.

The concept of a key adaptation is simple. A group of organisms acquires some structural feature that allows these organisms to exploit resources previously unavailable to them. This exploitation is accompanied by an increase, usually quite extensive, in the number of species in the group. A good example of a key adaptation is the development of wings by bats.

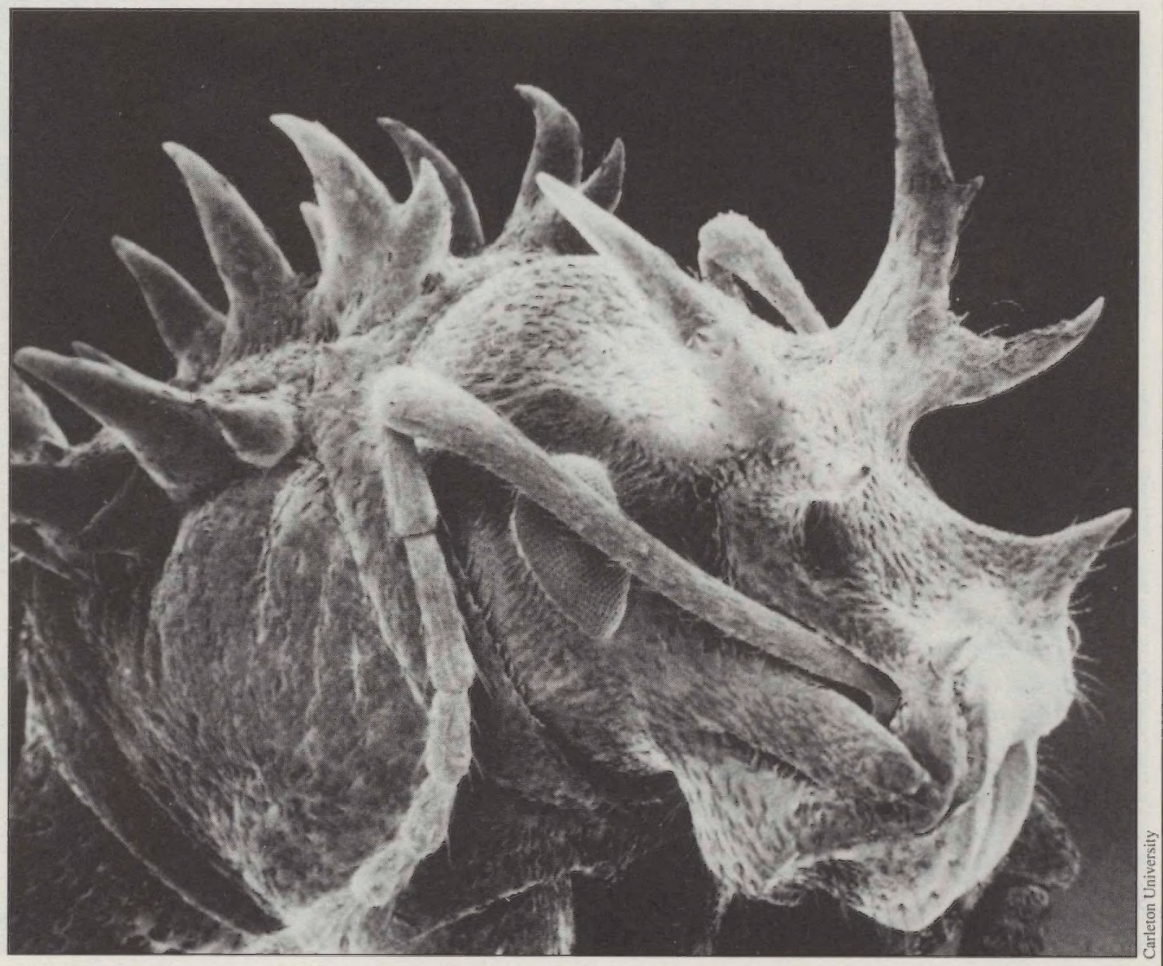
For weevils and their closest relatives, the key adaptation is the position of the mouthparts, an innovation reflected by one of their common names, the snout-beetles. Adult weevils and their relatives, like other beetles, have typical chewing mouthparts. Unlike other beetles, however, in which the mouthparts are close to the head, the mouthparts of weevils and their relatives are situated at the end of a snout of varying length. These mouthparts are used by the adults in feeding, but they are also used by all female weevils and females of closely related groups for another function: excavating the hole into which eggs are laid. Being able to excavate a deep hole in a particular plant structure is very advantageous because it protects the eggs from drying out, predation and parasitism. It also ensures that the larva, when it hatches, is protected and surrounded by food. No other beetles can dig such deep oviposition holes. As a result, weevils and their relatives have exploited plants more than any other group of beetles.

Nevertheless, the development of this unique structural adaptation is only part of the explanation for the remarkable diversity of weevils. After all, other groups of beetles closely related to weevils, but much less diverse, also have a snout and also use it to dig the oviposition hole. The other part of the explanation is the nature and history of the association between weevils and their relatives, and plants.

Primitive groups of beetles directly related to weevils are associated with fungi and primitive plants such as ferns, cycads and conifers, but only weevils are extensively associated with angiosperms, our most diverse and widely distributed group of plants. This means that the closest relatives of weevils were associated with primitive plants before the origin of the angiosperms. Geographic distributions and ages of fossils of these groups support this contention. Establishing that the closest relatives of weevils and primitive plants were associated before angiosperms evolved is a crucial point. These primitive plants, likely the extinct seed ferns, from which angiosperms evolved, already harboured a beetle fauna composed of weevil relatives. Since these beetles already possessed a snout and used it for preparing the oviposition hole, they likely fed on various plant parts, but particularly the reproductive structures (the most nutritional parts of the plants). As angiosperms evolved, the relatives of weevils were structurally adapted and already sufficiently diversified to make the best of the situation. The success of their weevil descendants is clearly demonstrated by their diversity and association with virtually all angiosperm taxa and angiosperm plant parts.

Recognition and documentation of this diversity has stemmed from the activities of scientists who study biological systematics. However, systematists are not concerned merely with describing and classifying species. Our work also deals with explaining biological diversity. In these days of increasing environmental awareness and growing interest in preserving biological diversity, we need to know not only what the diversity of life on Earth is, but more importantly, how it has arisen, how it is influenced and how it is maintained. Only then will we fully understand how to preserve it. Systematics will lay the groundwork for developing a new understanding and workable strategies to address these critical issues concerning the future of our world.

Robert S. Anderson
Entomology



Carleton University

An unidentified Amycterini from Australia, a "dinosaur" among the weevils.

The Activity Corner: Ottawa Valley Fossils

Four hundred and fifty million years ago: a nautiloid preys on a trilobite.

Imagine yourself watching seals and whales swimming in an icy sea. Or would you rather fancy diving for sponges along a tropical coral reef? Both of these environments were once in the Ottawa Valley. Twelve thousand years ago, toward the close of the last glaciation, the Champlain Sea was formed as glaciers began to recede and the Atlantic filled the depressed areas left in their wake. Five hundred million years ago, at the beginning of the Ordovician Period, the area was covered by warm shallow seas as diverse in life as our reef communities today.

The fossils of the Ottawa Valley are the remains of these fascinating lost worlds. Many fossils of Champlain Sea vertebrate marine life have been found, including the remains of whales, seals and fish. However, fossils of invertebrates from the Ordovician Period are much more common, since the rocks they are found in (limestone and shale) are predominant here.

Some of these fossil invertebrates may seem alien, but others are quite easily identified: clams, snails and sea lilies have changed very little during half a billion years. Brachiopods are superficially similar to clams in appearance and are very common in this area. The extinct "beetle-like" trilobites are also fairly common. Trilobites are rarely found complete but their moulted tails and other parts are readily found. This fantastically diverse sub-phylum of arthropods included swimmers, bottom-dwellers and burrowers. Their only known proposed predator during the Ordovician was the nautiloid, an extinct cephalopod (octopuses and squids) with a straight shell. Shells of some nautiloids found in this area have been 1.2 m long.

Unfortunately, "soft-bodied" life forms were not preserved here because of harsh conditions during burial. But there is still much to find. Look anywhere there is a rock outcrop, such as along roads, on riverbanks or lakeshores. Fossils in limestone usually mean a warm climate and a shallow sea environment. Fossils in shale reflect a deeper marine environment. Most of the best Champlain Sea fossils are found in calcareous clay nodules.

Before you begin fossil hunting, check about any regulations that may apply to where you collect and get permission before entering certain areas. Cliffs and quarries are good sites to look for fossils, but remember, you must be at least 16 years old to collect in active quarries. If you use a hammer, wear safety glasses. If you want more information about how to collect fossils, or want to have your fossils identified or want to trade them, come to the Museum's Collector's Corner (3rd floor east). If you live far from Ottawa, contact your local or provincial museum about the kinds of fossils that can be found in your area.

Keep your eyes open, fossils are everywhere. Some children start collecting by looking in the gravel in their driveways. The best fossil I ever found was an extinct relative of the starfish. It was in my own backyard.

Mike Leveille
Interpretive Programmes

From the Director's Desk:
A Museum for All Canada

Most people think of the Canadian Museum of Nature as the building that looks like a castle at the corner of Metcalfe and McLeod Streets in Ottawa. This building houses the public displays, and so is very familiar to our many visitors. Less familiar are the many buildings that house our collections, research laboratories, exhibit design and construction facilities, and normal administrative functions. All of this, however, is centred in Ottawa. What about the rest of Canada? How can we be a museum for the rest of the country?

Traditionally, museums reach out beyond their walls by publishing books. Our museum has a long and distinguished history in this field. Today we are the most active museum publisher in the country. Progressive museums also have travelling exhibits that circulate amongst other museums. Once again, our museum is by far the most active in building and circulating natural history travelling exhibits. They are so popular now that they are booked for three to five years before we have finished designing them. Within the research community, museums traditionally loan and borrow portions of each other's collections. All of these activities are a part of the fabric of our museum and they stretch across the country, as well as internationally. One of our temporary exhibits will be transformed into an international travelling exhibit that will visit as many as twelve countries in Europe. We are co-venturing with the Mexican government to create a major travelling exhibit on the mysteries of the Monarch butterfly.

What else should we do now? We have begun a vigorous programme of innovation to find new concepts to reach not only beyond our walls, but beyond the "walls" of the Museum traditions. For instance, with our help, the CTV series, "The Last Frontier," was designed for commercial television, but with a strong science and nature-based message. It was rated tenth overall in popularity on television in 1990, and third for Canadian productions. The Museum was recognized in every show's credits. The Museum initiated an audio cassette programme called "The Secret World of Animals." These are designed for radio broadcast and for personal use in walkman or car or home audio systems. The Museum has joined with a national group of volunteers in a programme called "everGreen" that holds a nature art show, inviting submissions from all across Canada. Artists from every province and territory have participated. The show is held in Ottawa, and this year we hope to have it become a travelling exhibit. Another concept we have initiated is to coventure with a large commercial retail shopping mall to display very life-sized models of whales in the atrial spaces, with explanatory exhibits at floor level. The pilot project, opening in the World Exchange Plaza in Ottawa, is being hosted by the Prime Minister's wife, Mila Mulroney, and the Speaker of the House, the Honourable John Fraser. We will extend it to other commercial venues, bringing the Museum to the people, rather than requiring the people to come to the Museum.

What's next? Our Board of Trustees, under the leadership of Dr. Norman Wagner, our Chairman, will discuss ideas of how the Museum can become a truly Canadian institution, representing us across the nation and to other nations. Do you have ideas you would like to contribute? If so, drop me a line, and I will make sure the ideas are presented to our Board for consideration in the discussions.

Alan R. Emery
Director

BIOME

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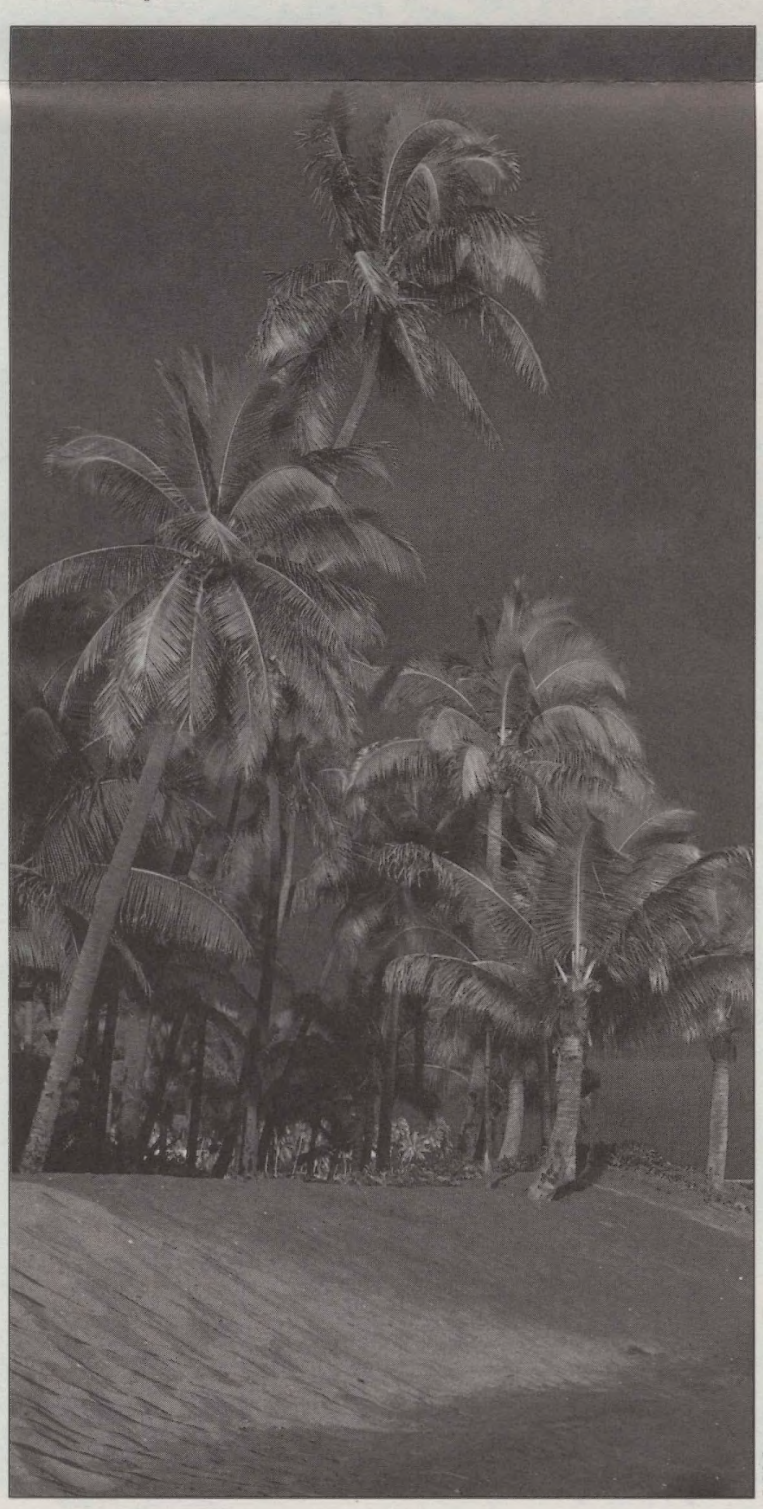
Coconut: The Tree of Life

The coconut palm (*Cocos nucifera* L.) graces the beaches of tropical shores and figures prominently in the romance of many oceanic islands. The tree, a monocotyledon related to grasses and sedges, provides more products of use to mankind than any other tree. In the Philippine Islands, the livelihood of about one-third of the country's population depends either directly or indirectly on this one tree species.

The coconut palm provides food such as coconut milk, coconut meat (the nut kernel), coconut oil (used in cooking) and oil-cake or poonac used as cattle feed. Fibres removed from the nut husk are used to make rope, mattings and smaller woven items (see photograph). The trunk fibres (not real wood) are used in home construction, furniture making and sometimes fence building. The leaves (called fronds in palms) are used in thatching house roofs and in weaving mats. Juice extracts from the flowers are rich in raw sugars and are converted into edible sugars and vinegar. Other extracts from the coconut itself are used in soaps and other toilet articles.

Coconut palms grace the shore of Viti Levu, Fiji.



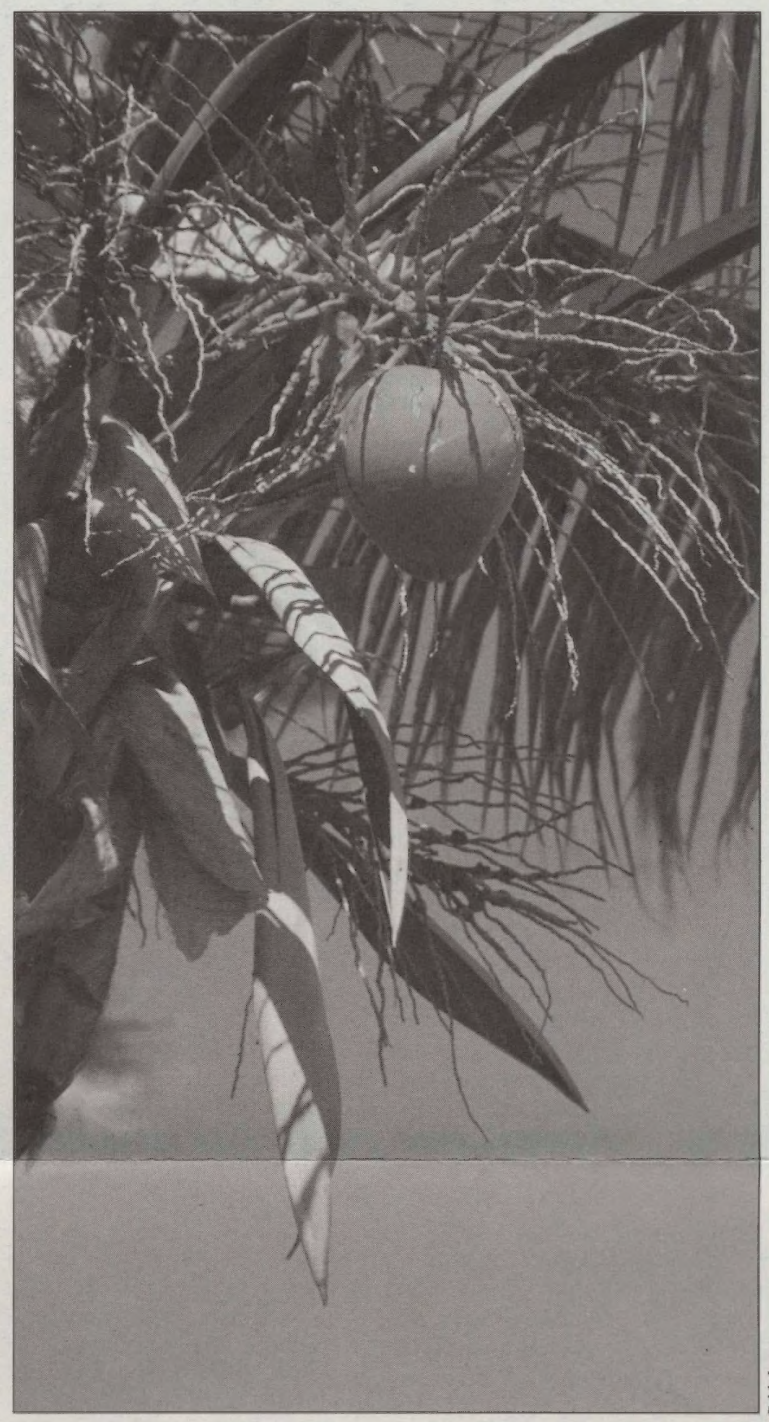
D.M. Jarzen

Human use of the coconut palm has been recorded at least as early as 1400 B.C. Indian medicinal literature refers to the presumed healing powers of the coconut (probably in reference to the coconut milk). While on an envoy to China, Arabian travellers in the ninth century noted that the Maldive Islands (a group of islands about 600 km off the coast of India) were covered with coconut palms. An Indian religious sect had introduced and propagated the trees on these islands for "humanitarian reasons."

Botanists and historians have tried to trace the origins and distribution of the coconut palm, which is found today throughout all humid tropical and subtropical mainlands and almost all tropical oceanic islands. The task has not been easy.

The coconut palm grows especially well near the sea, and its fibrous and "woody" fruit (the coconut) can float unharmed for long distances. Hence, it probably became widely dispersed early in its history. Its native home is thought to have been in Malaysia and the islands of Melanesia. This theory is partly based on the close association of a species of crab with the coconut palm. The robber crab, which feeds on the coconut, has body fats that more closely resemble coconut oil than animal fat. The distribution of the robber crab extends from the Cocos (Keeling) Islands in the eastern Indian Ocean westward across Indonesia and into the Polynesian Islands of the Pacific Ocean. Because the crab has not been dispersed by humans, its distribution is considered to outline the original distribution of the coconut palm.

Close-up of the nut of the coconut palm. The wiry, stick-like structures are the remains of the flowering stalks.



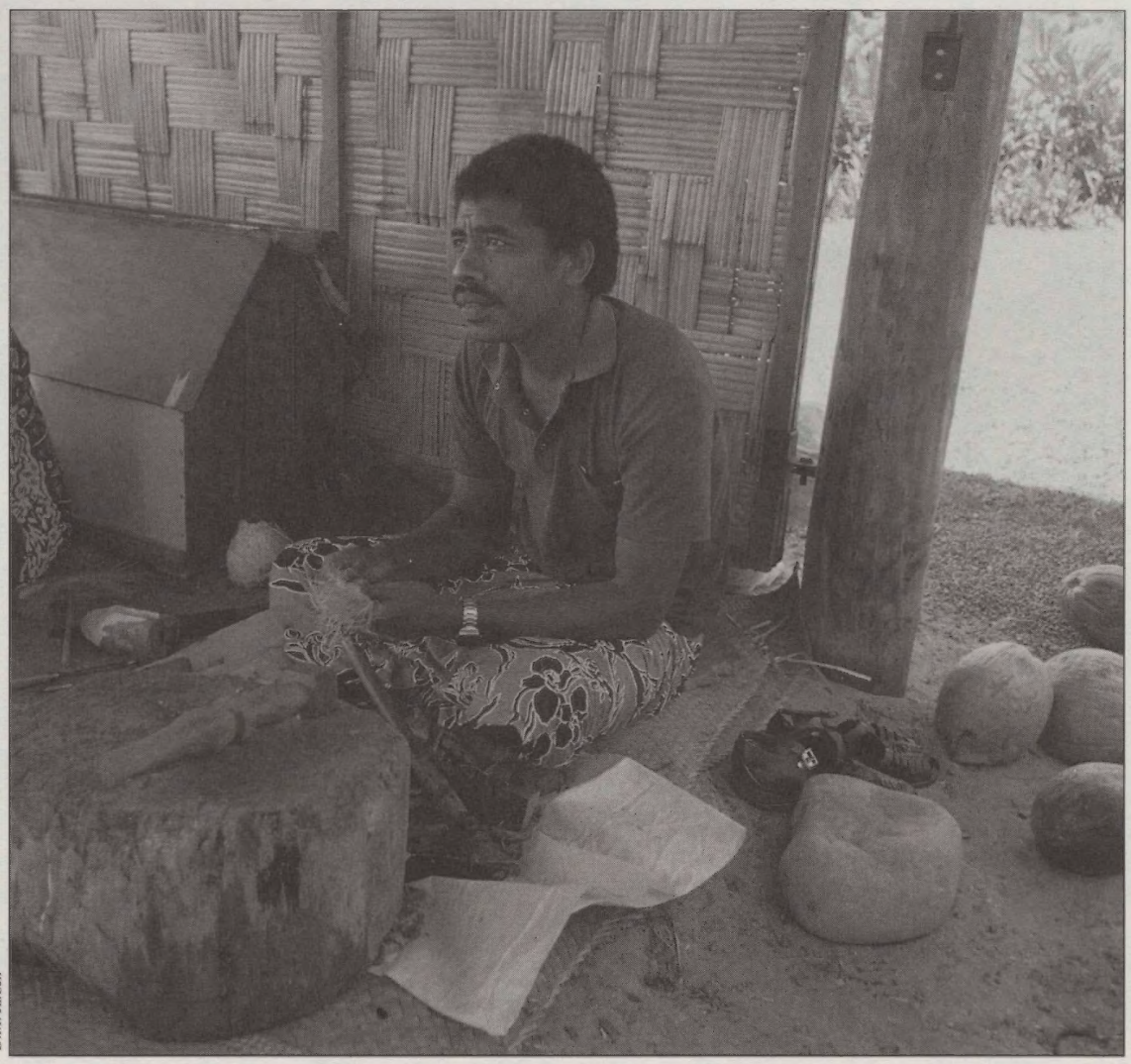
D.M. Jarzen

Fossil evidence tells us little about the history of the coconut palm and its place of origin. Fossils of palm nuts, similar to living coconuts, have been found in New Zealand and India in rocks dated from 5 to 40 million years old. However, because the fossils are not identical to living coconuts, their relationship to each other is speculative. Evidence gathered as recently as 1990 supports a Malaysian origin on islands in the ancient sea Tethys (approximately equivalent to today's Indian Ocean and South China Sea). From there, the coconut rapidly dispersed by floating to other islands in the Pacific and Indian oceans. When humans began to navigate the seas, the coconut palm was distributed along major sea routes from the Far East to the coasts of Africa and across the Atlantic Ocean to the New World.

The coconut palm tree has served humanity for thousands of years as a source of food, clothing and housing materials. It truly deserves the name "tree of life."

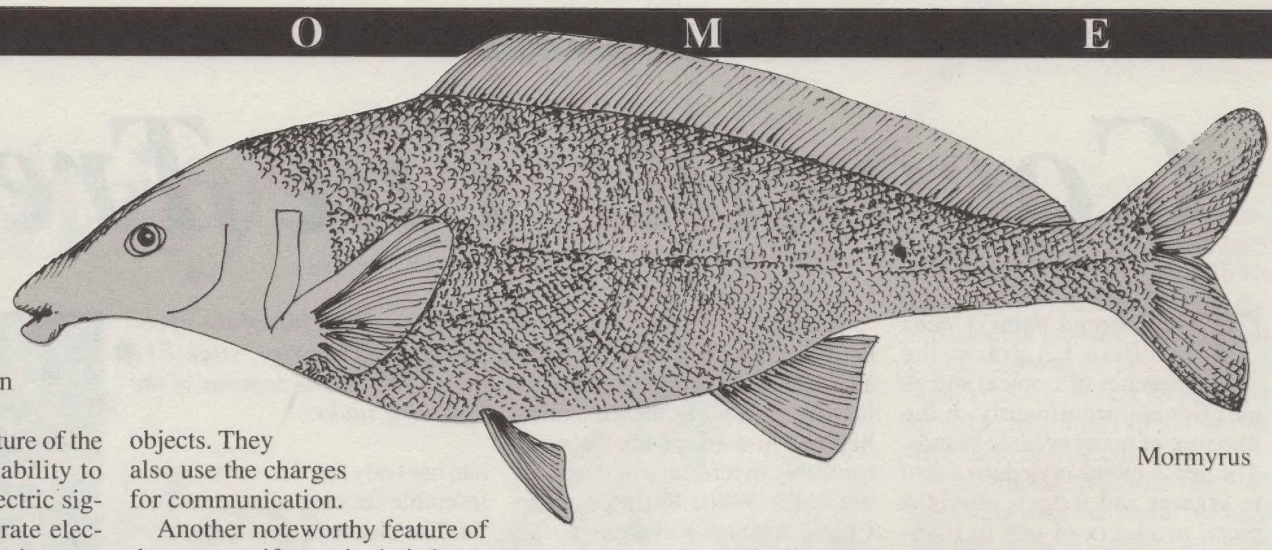
D.M. Jarzen
Paleobiology

A Fijian strips fibres from the coconut husk to weave into a twine for sewing.



D.M. Jarzen

Africa's Electric Fish



Mormyrus

Africa's fish fauna is unique in having numerous groups that are endemic (found only in Africa). Unfortunately the fossil record of these groups is poor, so studying their background and relationships is difficult. I recently took part in excavations in the western Rift Valley, Zaire, where many fossil fish remains were recovered. Analyzing these remains has pushed back the fossil record of some of the endemic fish taxa into the early Pliocene.

One of the most interesting groups is the Mormyriformes, remains of which were recovered in large numbers in the fossil deposits. Today this group is found in rivers and lakes throughout Africa, and includes fish that range from about 9 cm to 1.5 m in length, and come in a variety of shapes. Many have strangely shaped snouts. Aquarium enthusiasts may be familiar with some species of *Mormyrus*, which have an elephant-like snout.

The most unusual feature of the mormyriforms is their ability to generate and receive electric signals. The fish can generate electric charges using an electric organ located in the caudal peduncle, just in front of the tail. The organ is derived from muscle tissue. The fish use the organ to generate electric pulses constantly throughout their lives. The pulse frequency depends on the activity. The pulses create a type of electric field in the water around the fish. The charge is weak, usually less than 10 volts, and in mormyriforms is not used as an offensive or defensive weapon. The fish can receive electric charges using electroreceptors, which are located on their heads and on the dorsal and ventral parts of their bodies. Using the electroreceptors, they can sense changes in the electric field, and can identify the location of other fish and objects. They also use the charges for communication.

Another noteworthy feature of the mormyriforms is their large brain, which is assumed to help process the electric signals being received. The largest parts of the brain are the cerebellum and acoustico-lateralis areas of the hind brain. The ratio of mormyriform brain to body weight is unusually high for any vertebrate: 1:50, which is close to that in humans.

Because of the weakness of their electrical charge, it is suggested that mormyriforms cannot live in waters of high salinity and conductivity because these waters would hinder their ability to locate objects. Mormyriforms do not live in Lake Turkana, Kenya, for example, although they do live in the inflowing Omo River. Lake Turkana is very saline, but the Omo River is fresher. Fossil deposits around Lake Turkana indicate that mormyriforms did inhabit the lake at higher lake levels, when its waters were fresher.

Electrical sensing in mormyriforms replaces or lessens the functions of some other sensory organs. Most mormyriforms are nocturnal fish, and are blind or almost blind. Nevertheless some mormyriform species use electroreception to locate and catch other fish, although most have an herbivorous diet. The electric organ is also used for electric signalling in courtship and spawning.

Humans have had various reactions to mormyriforms, ranging from veneration to aversion. In dynastic Egypt, several species of the mormyriform *Mormyrus* were associated with the god Osiris, and therefore were not eaten as food. There are frequent references to them in ancient Egyptian hieroglyphs. In contrast, in some areas of sub-Saharan Africa it was believed that if pregnant women ate certain species of mormyriforms, they would give birth to deformed babies. In other areas, eating them was thought to induce sterility.

Further work on fossil mormyriforms should provide more insight into their behaviour and unique sensing abilities.

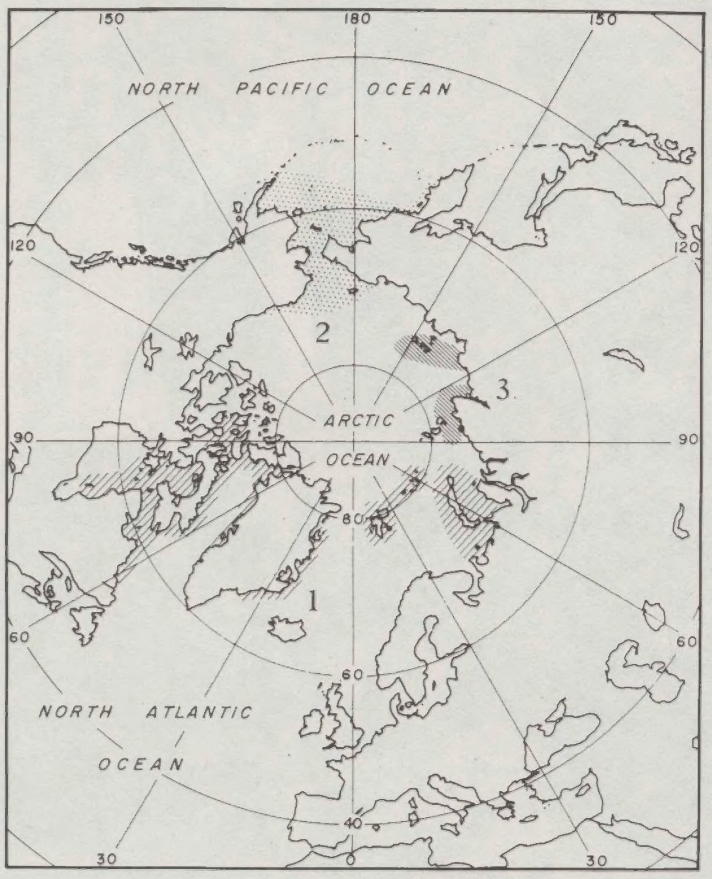
Kathlyn Stewart
Zooarchaeology

Walrus Near Montreal!

The Champlain Sea was a major feature of the landscape of eastern North America toward the close of the last glaciation. As the Laurentide ice sheet retreated north of the St. Lawrence Lowland (already depressed by the weight of ice), Atlantic Ocean water flooded in some 12,000 years ago. At maximum extent about 11,500 years ago this inland sea covered approximately 53,000 km^2 between what is now Quebec City and Brockville, including the lower Ottawa River valley and the Lake Champlain valley of New York and Vermont. As the ice sheet melted away, the land rose slowly and the sea drained back into the Atlantic, leaving behind fossils of plants, invertebrates and vertebrates.

Having studied remains of Champlain Sea marine mammals (ringed, harp and bearded seals; bowhead, humpback, finback and white whales) for many years, I wondered as early as 1977, why walrus bones had never been reported. After all they had been excavated from 14 localities in the eastern approaches to the Champlain Sea — almost to Quebec City.

The solution to this apparent problem was more a matter of time and luck rather than paleoenvironmental factors controlling walrus distribution, for in August 1990, farmer Jacques Daviau pulled some bones out of an excavation near his home at Ste-Julienne, Quebec, 50 km north of Montreal. Through Michel Bouchard, a geologist at the University of Montreal, I received the bones for study a few weeks later. I could hardly believe it — there were four pieces of an adult male walrus (*Odobenus rosmarus*) skull with fragments of sea shells plastered in grey mud to the roof of the cranium. But we would need to check the type and layering of the sediments at the site and get a radiocarbon date on bone from the skull before we could be sure that this was indeed the first Champlain Sea walrus record.



Present distribution of Odobenus rosmarus. *Subspecies are: 1, the Atlantic walrus,* O.r. rosmarus*; 2, the Pacific walrus,* O.r. divergens*; 3, the Laptev walrus, whose taxonomic status remains uncertain (from F.H. Fay, 1985).*

On a glowing day near the end of September, Jacques Daviau with several relatives, Michel Bouchard with his colleague Jean-Pierre Guilbault and I met at Ste-Julienne. Jacques had arranged for a local backhoe operator to clear a trench where the walrus skull had been found. This was a very stylish, enjoyable method of excavation — beats the hell out of shovelling! We quickly established that abundant shellfish of four kinds, as well as barnacles, were coming from a banded sand and clay zone nearly 1 m below a surface layer of sand deposited as the sea withdrew from its northern shore in this area. The walrus skull had almost certainly come from the base of the shell layer, but unfortunately no more bones were located during the excavation. Below the shell layer was a thick deposit of sticky, grey Champlain Sea clay — deep water deposits containing dropstones (During the course of their "life," glaciers pick up rocky debris, and then fragments of ice "calve" or break off into seawater and melt, angular stones from the debris occasionally dropping into the bottom mud.)

Our field work suggested that walruses (they are gregarious) lived in the area after the sea had reached its maximum extent, and had probably fed on several of the species of shellfish represented in the banded zone. In March, Michel received a radiocarbon date indicating that the Ste-Julienne walrus had died a little more than 10,000 years ago. Our suspicions were confirmed.

Although many samples of clay were taken at 10 cm intervals below the shell layer, unfortunately none yielded microorganic remains of ostracodes and foraminifera that have been found useful in providing estimates of ancient sea temperature and saltiness.

In looking more closely at the partial skull (front part of the cranium with tusks and other teeth), I noted that the tusks are rather short, straight and spreading little at the tips — more like Atlantic than Pacific walruses. Among specimens to which I compared the Ste-Julienne fossil, the closest match was a recent male Atlantic walrus from the Northwest Territories estimated to have died at about 15 years of age. The circumference of the tusks (156-159 mm) of the fossil suggested an age-at-death of approximately 14 years (female measurements are much smaller). By sectioning a premolar tooth and examining microscopically the cementum layer around the root, I found 14 yearly rings. This supported the earlier estimate of age-at-death.

Probably walruses reached farthest south near the maximum extent of late Pleistocene glaciations. Evidently Pacific walruses, or their forerunners, occupied more southerly waters along that coast [e.g. The Qualicum walrus from Vancouver Island (see *BIOME* Vol. 7:2, 1987), and walrus fossils from San Francisco Bay, California]. Atlantic walruses, or their ancestors, reached South Carolina.

The Ste-Julienne walrus is not only the first record of that species from the Champlain Sea, but it fills an important gap in the animal's postglacial range. Its age lies between 12,800 year-old remains from the Bay of Fundy and 7,300 year-old remains from Bathurst Island in the central Canadian Arctic Islands. This helps us to understand better the northward shift of the species since the Laurentide ice sheet began its retreat.

Still, there are many more questions to answer about Champlain Sea mammals. Sitting at Jacques Daviau's kitchen table in my sweaty field clothes, drinking a potent cup of coffee, I pointed to him and said in my broken French "The next thing we need from you is a polar bear fossil!"

C.R. Harington
Paleobiology